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THE ELECTRIFICATION OF NORWAY OVER A PERIOD OF 100 YEARS IN PARTICULAR THE UTILIZATION OF WATER POWER*

by

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Some features of the
ELECTRIFICATION OF NORWAY OVER A PERIOD OF 100 YEARS

Experiences which may be useful for certain developing countries - in particular concerning the utilization of water power sources.

Introduction

Development strategies

1. Electrification of a country, or of an area, may be organized in accordance with various strategies of development:

   a) The step by step development of internal sources of energy that are large and concentrated, in this way drawing benefit from the fact that the cost per produced unit usually decreases with the size of the works - the economies of scale benefit.

   b) Electrification first of areas with concentrated activity - urban and industrial areas - by means of power production plants of suitable size. From these core areas, the power supply system is extended to areas with sparser population and less concentrated activity, i.e. to rural areas.

   c) Greater emphasis on the electrification of small communities and rural areas such as these do not lag behind in relation to the development of the supply services in urban areas.

2. The profitability of electrification projects are too often considered only from the point of view of the supply undertaking alone, i.e. economic profit for the supply undertaking will be the most important factor determining whether the project will be realized, and whether it will be possible to finance it, i.e. whether the finance institutions will be willing to give a loan for the project, see 1.a and b.

3. If the secondary and tertiary effects of electrification are considered from the point of view of society as a whole, it is possible that the plans will be formed otherwise, see l.c.

4. It may not be wise to make a direct transfer of technological solutions from countries with total electrification and with extensive industrial activity to countries where, in some areas there is no electrification at all, or where this is just in the early stages.

3. Electrification of an area means a great deal to the population and for the activity in the area. Important elements in the planning for electrification are:

a) the attitude of the people living in the area towards the plans - usually this is very positive

b) the possibilities for potential subscribers themselves to take an active part in the implementation of the plans - that is to say, to effect electrification in practice

c) the possibilities for making use of local labour and local resources when implementing the plans

d) the use of uncomplicated (simple) technical solutions

e) the utilization of local energy resources

f) secondary effects of electrification - light at home and at work, auxiliary services, introduction of television (nation building), mechanization of local industrial processes for production of agricultural and fisheries products, small-scale industry

g) secondary effects by means of educational services that are possible only where electricity is available - for example, adult education programmes on television, vocational training in mechanics, machine maintenance etc.

6. From the point of view of society the best programmes for development are these aimed at electrification of areas where people traditionally live and have their means of livlihood, rather than areas where the market is best for the sale of electricity in the preliminary phase. Electrification of the traditional areas for culture and activity, that is to say, the rural areas, with their agglomerations, will counteract the tendencies towards urbanization which often make themselves felt when too much emphasis is placed on building-up so-called centres, which in turn often leads to the development of slum districts as a result of overloading of the service facilities in the towns (transport, water supply, sewage, waste disposal), to unemployment, unrest and political instability.

7. Electrification provides extensive possibilities to influence the life of the people in rural districts in such a way that they want to stay there and work there. There are many arguments for choosing development strategy c, even though more narrow economic considerations may point to strategy b. The electrification programme for Norway in the last 40 years has included many elements of strategy c.

8. The purpose of this report is to point out some of the features of the history of electrification in Norway which may be of interest in areas which are about to start, or have just started, to develop an electricity supply system. It will take particular notice of the importance of an initiative by the local population and of the utilization of local, small sources of water power. Consideration will also be given to the question of professional assistance and financial support, together with the importance of the development of a strong technological milieu with possibilities for harmonization, coordination and standardization of solutions. The development of internal industry for the delivery of equipment for electrification will also be discussed.

Norway's electricity supply and electricity consumption today

9. It can be of interest to look at where Norway stands today. By tradition, Norway is a country with a strong rural structure - spread over the whole country, with population and activity along rivers and lakes, along the fjords and on islands. General geographical data are found in Appendix 1.

10. Norway has a very high energy consumption. This is in part due to climate, in part to the high degree of industrialization and mechanization, which again is a result of the very extensive water power resources. The supply of electricity is up to 99.8% based on inland water power. Water power electricity represents about 58% of the total inland energy utilized by the consumer, see Appendix 2. Table 1 shows the dimensions of the water power stations.

Table 1.
Water power stations in Norway according to size per 31.12.1978
(see also Table 3).

Size Kilowatt	Number	Total capacity kilowatt	Mean annual producibility Gwh
0- 100	Unknown	-	Insignificant
100- 1 000	156	66 000	about 200
1 000- 10 000	190	680 000	3 300
10 000-100 000	186	6 148 000	30 600
> 100 000	55	10 737 000	52 700
SUM > 100	587	17 631 000	86 800

(for units etc. see Appendix 2).

11. Water power stations are spread over the whole country. Practically the whole of the country's power supply is interconnected in a system of 420 kV (kilovolt = 1000 volt), 300 kV and 132 kV transmission lines. A 420 kV tie line to North Norway is being constructed.

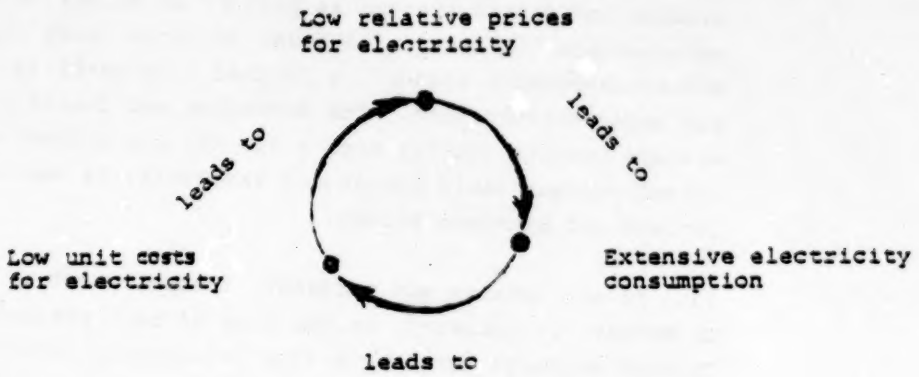
12. The Norwegian power system exchanges power with the Swedish and Danish systems as part of an extensive Nordic co-operation. A total of 5 power exchange lines cross the Norwegian-Swedish border. A further 2 connections (420 kV) are under construction. The Norwegian and Danish-Jutland systems operate jointly over a 500 kV, 130 kilometre long direct current cable across the Skagerrak, the sea between Jutland and Southern Norway.

13. To all intents and purposes, thermal power is found in Norway in industry, in the form of back pressure plants. Through exchange agreements with neighbouring countries, Norway is ensured a supply of thermal power in particularly dry years. 1977 was a dry year in Norway, and in that year, power was imported. Usually a certain amount of power is exported to neighbouring countries from time to time. Norway also has en agreement with the Soviet Union for the renting of a small amount of power over a 150 kV connection in the northern area.

14. The total developable water power potential in Norway is estimated as having an annual production capacity of about 160 TWh, given mean water conditions. About half of this has been developed up to now. Some uncertainty is connected with the remaining potential as a result of interests of conservation. Decisions have been made, or proposals put forward, to conserve about 20 TWh annual production capacity. Thermal power must be utilized if the demand for electricity continues to increase. Attempts are being made to reduce the further increase in consumption.

15. Characteristic for the electricity supply in Norway is that the system provides the consumers with a relatively large amount of energy. This gives a low cost for each unit, which in turn means that prices can be kept low. This results in a greater consumption of electricity; that is to say, electricity supply accounts for a larger proportion of the energy supply. These repercussions are illustrated in Figure 1.

Figure 1.



At the start of electrification, or in the case of sparsely populated districts it may be difficult to achieve a distinctly cost-reducing effect in this cycle. It has been possible in Norway in spite of the quite often very unfavourable geographic conditions and settlement structure.

The organization of the electricity supply

16. The electricity supply is in the hands of 294 distribution undertakings, see Table 2, and 74 wholesale undertakings.

Table 2.

The size and organization of the electricity supply per 31.12.1978.

Size of electricity supply undertaking, by no. of subscribers	Municipally owned electricity supply undertakings		Privately owned electricity supply undertakings	
	No.	% of total subscribers	No.	% of total subscribers
More than 100 000	2	20	0	0
10 000 - 100 000	36	41	1	0.5
1 000 - 10 000	166	33	36	4.0
0 - 1 000	23	1	30	0.5
Sum	227	95	67	5.0

17. Power station capacity is owned by the State (28%), municipal and county authorities (52%) and private undertakings (21%) - private undertakings comprise in the main industrial companies producing electricity for own use. The State owns and builds the greater part of the country's main transmission work - 300 kV and 420 kV, and is responsible for the exchange of power with abroad. About half the State's power production goes to power-intensive industry.

18. Public interest - municipality and county authorities, and cooperative units, dispose over almost the entire distribution of electricity in Norway.

19. The wholesale supply undertakings and the distribution undertakings collaborate on matters of common professional interest through their association - the Association of Norwegian Electri-ity Supply Undertakings.

20. The association "Samkjøringen" - the Power Pool of Norway - ensures the best possible joint operation of the total system, and therefore the best possible utilization of the resources at the disposal of the total existing system, water inflow, reservoirs, power station capacity, power exchange facilities and marketing possibilities for occasional power. Firm power is not sold through "Samkjøringen" but by contract or agreement between wholesale undertaking and distribution undertaking.

21. Thus the supply of electricity is the responsibility of a large number of independent units working in collaboration with each other and with the authorities, - in particular with the Norwegian Water Resources and Electricity Board (NVE).

NVE - a unique institution

22. The Norwegian Water Resources and Electricity Board (NVE) is, in principle, a peripheral authority working according to instructions based on an Act passed by the Storting (the Norwegian Parliament) in 1960. NVE is attached to the Ministry of Petroleum and Energy and is organized into four directorates. In addition to planning, bulding and operating the state power plants and transmission system, NVE contributes, through its activities, towards the best possible utilization of the total resources from the point of view of society as a whole. Furthermore, the citizens are ensured a satisfactory electricity supply, and that the electricity can be used without danger to life or property. This is based on a fairly comprehensive legislation which has been built up over the years - the first Act was passed already in 1896. It is effected in practice by NVE technical staff taking an active part, together with planners employed by the electricity supply undertakings, in preparations for further extensions to the electricity supply system.

23. By means of conditions laid down in connection with the granting of concessions it is ensured that the produc-

tion and transmission plants are developed in such a way that the country's total system is as economic as possible and involves a proper use of resources. NVE is also working on plans for the organization of the electricity supply into a smaller number of more rational units, on the economy of the electricity supply, on questions of standardization, on concessions and on safety matters relating to the supply and use of electricity.

24. NVE also deals with technical questions connected with water power resources - including hydrological investigations of rivers and glaciers, and various ways of preventing floods and movement of ice in rivers.

How electricity supply development started in Norway

25. On the basis of the above short report of the status of the actual electricity system in Norway I shall now go right back to the start and give a summary of developments during the almost 100 years that have passed since the first electricity supply undertaking began to function.

The situation in Norway at the turn of the century

26. The Kingdom of Norway became united about 900 A.D. From 1380 to 1905, Norway was periodically united with its neighbouring countries, Sweden and Denmark. Norway's present constitution dates from 1814. In 1905, the last Union - with Sweden - was dissolved. Consequently, at the same time as electrification began, a strong national feeling prevailed in Norway, though the influence from and contact with the other Nordic countries and with the rest of Europe was strong. In many ways this was an active period, both industrially and culturally.

1880-1937: First phase in the electrification of the country: preliminaries.

27. Electricity from water power was produced in Norway

already in 1877. By 1885 there were about 30 small water power plants in operation. In the following years, before and after the turn of the century, it was primarily the pulp and paper and the mining industry that developed water power for their own activities. Most of the companies were owned by foreigners who brought with them ideas, knowledge and capital from their parent companies.

28. The development of power for ordinary consumption started about the same time. In some places this was based on thermal power, but water power soon became the dominating, or the only source of electricity.

29. In 1914 there was an electricity supply undertaking in about 90% of all the towns, and a total of 130 such undertakings in rural districts. By 1921, all the towns received electricity and the number of electricity supply undertakings in rural districts had increased to about 340. The load was about 170 watt per inhabitant in the towns and about 100 watt per inhabitant in the countryside. In 1936, the number of electricity supply undertakings was about 440, and 73% of the population had electricity. The load had increased to almost 400 watt per inhabitant in the towns and about 200 watt per inhabitant in rural districts.

30. Traditional interests connected with water courses were timber floating, transport by row-boat, fishing and primitive saw-mills and flower mills.

31. Foreign interests made themselves felt in industry, particularly in the years just after the turn of the century. This was obviously a result of the large and favourable sources of water power. There soon arose a fear that developments would be dominated and controlled by foreign industrial companies, and this was perhaps the most important subject for discussion in the political arena in the years after the dissolution of the Union. The background for this was that,

in Norway, the landowner owns the rights of disposal over the water courses. Thus water fall rights could be sold like any other property. Foreign companies with much capital acquired important rights over the water falls. Considerable buying-up occurred.

32. All this led to a fear that water power developments and the establishment of industry would take place outside the control of the authorities. Norwegian authorities wanted to be able to exert a greater influence on developments. Therefore they introduced the Concession Acts. These were passed in 1917, and gave the authorities control over the purchase of waterfalls, the regulation of water flow and the marketing of the power produced. Further, the Act includes regulations stating that all water power plants shall revert to the State after 60 years, without economic compensation. In the main, the Concession Acts were made to apply to both foreign and domestic companies.

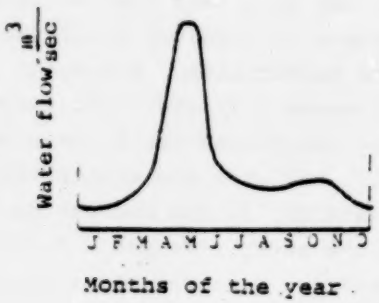
33. It was not least industrial development, based on water power, that led to the electrification of Norwegian society. The use of electricity in industrial processes and in the local industrial community showed how electricity could be used by people in general. Knowledge of water power technology spread, and caught the interest of people in neighbouring communities and in the municipal administration. Organizations in the form of cooperative societies, private companies, and municipal and county companies were created by enterprising persons all over the country. The main interest was in the use of electricity for lighting in the home, for handicraft firms and for small industrial enterprises. It was shown that motors could be operated much more profitably by electricity than by the combustion engine.

Water power sources with favourable properties

34. Norway's topography and precipitation conditions are very suitable for the utilization of water power, see Appendix 1. Figure 2 gives a schematic picture of the inflow

into a typical Norwegian water course in the course of a year. Precipitation in the form of snow gives little inflow in winter (December to March). The thaw causes floods in spring (April to June).

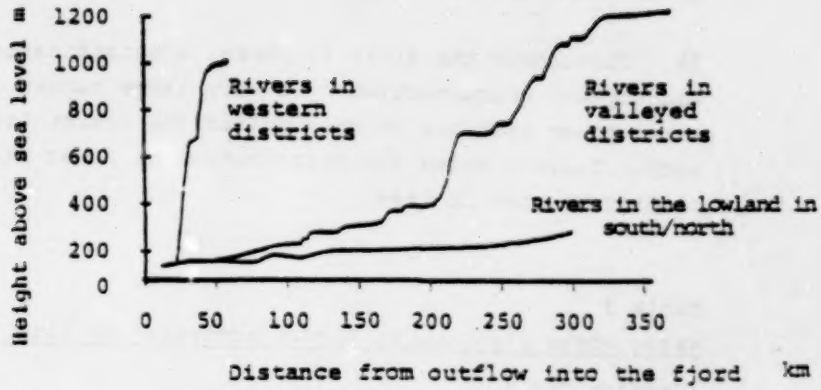
Figure 2.



35. At the west coast the rivers plunge steeply over falls and through gorges, down from the mountain plateaus at the innermost end of the fjords which stretch far inland. On the eastern side of the mountains the rivers flow more gently into the sea. Practically over the entire country it has been possible to find water courses with suitable inflow, and falls where conditions are favourable for developments with a view to meeting the need for electricity in nearby populated areas and rural districts. Often there has been a choice between a number of water power sources. This widespread availability of water power was particularly suitable for electrification of our far flung country, with its scattered population.

36. Figure 3 shows three typical water course profiles in Norway.

Figure 3.



37. Naturally enough, the demand for electricity arose first in the central settlements - that is to say in towns, and rural agglomerations. But it must be pointed out that the original settlement in Norway, apart from the trade centres at the coast, was spread over the rural districts. Until the middle of this century, agriculture and fishing were the most important means of livlihood. So people lived scattered. Most of them owned (and still own) their farm and their soil, and act and live independently. From an economic point of veiw, electrification of these outlying districts was a more difficult task than to electrify the centres.

38. Through the Concession Acts, the authorities provided the conditions necessary for a controlled development of water power, but the State did not concern itself with the development of an electricity distribution system. There were exaggerated expectations in connection with the use of electricity for operation of the railways, and the State bought up a number of fall rights for this purpose. In addition the State gradually built some larger water power stations

with transmission plants and sold power wholesale to industrial companies and to distribution supply undertakings.

39. Throughout the first 50 years, electrification of the country was characterized by a very large number of small water power stations which supplied the nearby local community. Table 3 shows the distribution of power stations according to size in 1944.

Table 3
Water Power Stations in Norway according to Size, 1944
(Compare Table 1)

Size Kilowatt	Number	Total kilowatt capacity
0- 100	1463	37 200
100- 1 000	355	121 200
1 000-10 000	146	454 300
> 10 000	45	1 688 500
SUM > 100	546	2 301 200

(for units etc. see Appendix 2)

40. The advantages of joint operation of isolated production and supply systems gradually became apparent. Transmission systems from the larger water power stations were connected to enable an exchange of power between them. State-owned plants formed important components of this system.

Electrification of rural districts lagged behind

41. In 1938, electricity was available in the home for about 75% of the Norwegian population - which at that time counted 2.8 million inhabitants. The approximately 700 000 who still had no electricity lived in sparsely populated areas, that is

to say, in the valleys, up into the mountains, and on islands along Norway's long and weatherbeaten coast. It was relatively costly to build a supply system in these areas because of the scattered settlement. Furthermore, as a rule people were not so well off in these districts, and this made for a poorer market. To extend the supply system to settlements on the islands required either cable connection under the sea, or a power production plant on the island itself. In many cases this would have to be a diesel power station, and this is much more costly than water power. Because of the economically favourable water power sources, people had become used to the idea that electricity should be cheap in Norway.

42. The economy of the population in sparsely populated areas provided a poor foundation for building up an electricity supply there. A total electrification of outlying districts could not be carried out on the initiative of the local population alone. This gradually attracted considerable concern in political circles.

1938-1961: The second phase of electrification, assistance to outlying areas.

State subsidies for development of electricity supply

43. It was thus difficult to carry out electrification of rural districts without support from the society as a whole. 1938 the Storting approved an arrangement whereby financial support was provied for the building of electricity distribution plants in sparsely populated areas. This support was given to the distribution companies for the implementation of specific projects, that is to say, mainly transmission and distribution plants, but also power stations. This can be said to be the start of phase no. 2 in the history of electrification in Norway.

44. Until quite recent years, the State obtained funds for this arrangement of subsidies by requiring a levy on all electricity consumption. NVE was given responsibility for implementing the arrangement, that is to say, for receiving plans for projects, assessing these, and making a priority ranking of projects suitable for subsidy. Financial support is provided by the Ministry on the basis of recommendations from NVE.

45. Largely because of this arrangement of subsidies, Norway is today fully electrified, or in other words, all persons living in Norway have a proper supply of electricity.

46. About 300 people live in such remote places that it has not been possible to connect them to the normal distribution system. These are given financial support for the purchase and operation of diesel aggregates, such that they pay about the same for the electrical energy they produce themselves as they would have had to pay for electricity from the electricity supply undertaking in the locality.

47. Funds for support were small in relation to requirements. The following guidelines were practised: Available money was rationed, so that all were given a certain supply of power as soon as possible. It was impossible to place strict requirements upon the quality of deliveries and this led to poor voltage conditions, large losses and often interruption of current. Nevertheless, this was preferred rather than giving each plant a larger dimension with an eye to the future, thereby delaying electrification of other areas.

Organization of distribution undertakings

48. We have described earlier how the electricity supply undertakings developed as a result of local initiative. An attempt was made to attract local initiative also when building up the electricity supply in sparsely populated areas. But here the State, represented by NVE, had to make a more active effort to get the distribution companies to take on the task. First of all, an attempt was made to add to existing electricity supply undertakings such that these,

through subsidy arrangements, were able to extend the distribution system at the limits of their supply area. Where this was impossible, new undertakings were initiated.

49. The distribution companies given the responsibility for supplying sparsely populated areas - as a condition for being awarded subsidies - maintained certain minimum prices for the electricity they sold. The publicly elected Boards of the distribution companies wanted to keep prices as low as possible. The authorities are apt to consider electricity prices from a social standpoint. The central authorities, by means of the taxes which are used as part of ordinary national economic policy, are able to influence the economy of the electricity supply companies. Even so, the economic foundation for a number of the companies supplying electricity to sparsely populated areas has not been too good.

50. This keen engagement is in many ways beneficial. The local pupulation are able to make their views and interests known through the publicly elected Boards and the municipal and county councils. This has put political pressure on the central authorities to find solution to the problems facing the districts in connection with the supply of electricity.

Levelling of prices

51. Electricity prices which vary from one supply undertaking to another are a result of the extent of self-management prevailing in the Norwegian electricity supply system, but are also closely connected with the extremely varying natural conditions under which the various supply units work. Nevertheless it is an important political objective that prices should be as equal as possible in the different areas. The electricity supply undertakings with the best economy are often those that began at an early stage to develop their own water power. This is partly related to conditions of costs for power production. Older water power stations, that are no longer burdened by loans, produce electricity at a very low cost (about 1-2 øre/kWh).[x] Distribution undertakings which receive power from newer plants are burdened

[x] 1 øre ≈ 0,2 US cent

with higher costs for their supply of power. This is due to inflation and to higher capital costs.

52. Further, the fact that older distribution undertakings supply more densely populated areas, gives them a better economic foundation. Characteristic figures are the number of subscribers per km distribution line and the sale of electrical energy per subscriber per year.

Increased load led to problems

53. It has become apparent that the economic capacity of distribution undertakings in sparsely populated areas has been insufficient for them to consolidate their system in step with the increase in load. This results in poor supply, which may mean that the subscriber reduces his consumption - for example by using other forms of energy. This in turn again helps to disturb the economic basis for the distribution undertaking , compare figure 1.

54. The central authorities' efforts to counteract these problems have been aimed at:

a. An extension of the above mentioned subsidy arrangements to include consolidations to the system - not merely construction of the original initial supply system.

b. Providing low-interest loans for consolidation of the system through the Norwegian Municipal Bank - which is a finance institution founded upon State guarantees.

c. A rationalization of the organization, and the combination of smaller units into larger ones - in particular the coordination of companies responsible for supplying power to sparsely populated areas with other supplying densely populated areas and centres. It has been shown that in order to achieve this, financial support has to be provided to strengthen the poorer system before the combination takes place.

The need for coordination of the electricity supply

55. As electrification of the country progressed there was shown to be a need to a coordination of further developments and a rationalization of the organization of the electricity supply. Technical plants were extended on the basis of plans prepared locally. These gave little or no consideration at all to the advantages of joint operation with the neighbouring system. As late as in 1957, there were 27 larger or smaller supply systems with no interconnections between them. The need for coordination was obvious.

1962-1978: Third phase of the country's electrification, coordination and joint operation.

56. NVE was reorganized in 1960 and was given the additional responsibility of coordinating the further development of the electricity supply. A planning unit was established which was to prepare nation-wide plans for the system and ensure that each component - i.e. power-production plants, transmission systems and tie lines between systems to be built in addition to the existing system - was suitably dimensioned and operated in such a way as to be of best possible benefit to the system as a whole, irrespective of who owned the component. This introduced what may be looked upon as the third phase in the history of electrification in Norway. NVE has developed an expertise which, in collaboration with the power companies, ensures that this objective is achieved. As mentioned earlier, the Association of Norwegian Electricity Supply Undertakings, and "Samkjøringen" - the Power Pool of Norway - also work in this direction.

57. Through NVE, at the State Power System, the main transmission system for the country and connections with abroad are developed in accordance with the nation-wide plans prepared by the above mentioned planning unit. It is necessary to emphasize the importance of close collaboration between this planning unit and planners employed by the power companies. At the same time it must be ensured that NVE's planning unit is also able to act independently of the power companies.

58. In addition, NVE assists in efforts to make the distribution of electricity, and the wholesale supply in the districts as rational as possible.

The basis for coordinated planning

59. NVE's activities in this connection are based on a special Act - the so-called Electricity Act (latest version of 1969). Pursuant to this Act a licence is required for all electricity plants with a voltage higher than 1000 volts. In principle, the Licensing Authority does not give a license for plants that are not in accordance with the coordinated plans. In practice, of course, only the most important components of the system are assessed closely by the central planning unit. Components farther out in the distribution system are planned by local bodies and are not considered in detail by NVE. All power production plants, however, are given special consideration, both from the technical and the economic standpoint. Attention is also given to the question of who will be issued with a license to carry out the development.

Standardization

60. Each individual power supply unit has been given a relatively free hand in the choice of equipment for the development of the supply system. This has led to the use of many different types of equipment. At a very early stage, problems arose because some chose direct and others chose alternating current in their respective distribution systems. The greatest problems have been associated with choice of system voltage for low-voltage and high-voltage distribution.

61. Additional costs to the companies when systems with different voltages were to be combined resulted in the demand for a standardization of voltage level. Nowadays, 22 kV is preferred for high-voltage distribution - particularly in rural districts - 66 kV and 132 kV for the high-voltage feeding systems. The problem is that changing over to another voltage level is very costly.

62. The authorities also introduce a certain standardization by making sure that norms and standards are complied with in respect of the plants for which a licence is applied for.

63. The Norwegian network has a frequency of 50 Hertz. It is operated in synchronism (tied together) with the Swedish and Finnish networks and with parts of the Danish. The remainder of Denmark (Jutland) is operated in synchronism with the main European system.

International cooperation concerning norms and standards

64. For many years, Norwegian specialists and experts from the power supply and electrical industries have taken an active part in the work of the International Electrotechnical Commission, aimed at a standardization of, and norms for systems and equipment. This is expressed, for example, in requirements for the materiel forming components of systems, value norms, system voltages etc.

65. Similarly, Norway is represented in ISO (International Standardization Organization).

66. The standards and norms issued by such organizations are accepted as Norwegian norms and standards - nearly always without alterations of any kind. This gives the advantage of being able to purchase materiel on the international market at the lowest price and be sure that it can be replaced by other equipment.

Quality requirements for electrical consumer equipment

67. Electrical equipment for use in Norway is subject to control in accordance with special legislation. This control is the responsibility of The Norwegian Board for Testing and Approval of Electrical Equipment(NEMKO - Norges Elektriske Materiellkontroll).

68. Electrical installations at the electric supply undertakings are controlled by NVE, Directorate of Electricity. This task is carried out in accordance with special legislation. NVE has delegated control of distribution system

installations and of subscribers' electrical installations to the electricity supply undertakings.

69. There are very few accidents in Norway resulting from the use of electrical equipment, but electricity may be cause of fire in buildings. This is probably because it is very usual to build houses of wood in Norway, and that, because of the climate, most buildings have an electric source of heating.

70. The Act relating to the Inspection of Electrical Installations also lays down minimum requirements regarding the competence of persons who work with, and are responsible for the erection and operation of electrical installations.

71. Strict control that these quality requirements are complied with serves to protect both life and property.

Norwegian Industry as supplier for development of electricity supply.

72. Norwegian electrotechnical industry has developed in step and together with the electrification of the country. Components have been manufactured in part in factories owned by foreign industrial concerns, in part on the basis of licences purchased by Norwegian firms. Gradually, the situation has become that Norwegian firms have dominated the manufacture of electrical materiel.

73. Today, the Norwegian electrotechnical industry is capable of delivering all the materiel necessary for the further development and renewal of the electricity supply network. A certain amount of equipment is imported as a result of free competition, but in return, Norwegian electrotechnical industry exports materiel for power development over large parts of the world.

74. There has been close collaboration over the years between Norwegian electrotechnical enterprises and similar firms abroad. This has been of economic benefit and has stimulated the exchange of know-how.

75. Norway has a liberal system of trade allowing, amongst other things, foreign firms to compete on the Norwegian market. This has caused problems, in particular for the purely Norwegian firms, which operate on a market that is relatively small in comparison with that of the larger foreign concerns.

75a. Norwegian contractors, together with the NVE-State Power System perform the construction work of power stations and main power lines. The electricity supply undertakings build much of the distribution system under own management. Norwegian consulting engineers are experts in the field of water power and electricity supply development.

Development of the technological milieu

76. As mentioned above, there was extensive foreign influence during the first phase of the history of electrification in Norway. That Norwegian people have shown such a keen local interest in electrification is probably a result of local democracy, the "help towards self-help" attitude of the central authorities, and that electrification could begin with the utilization of water power sources which were available everywhere. Geographically, the technological milieu was widespread.

77. Technical education began in connection with mining operations in the last century. The Norwegian Institute of Technology was founded in 1910. Mining, industrialization and electrification of the country led many young people in small towns and rural districts to seek a technical education.

78. Not least the development of an electricity supply - and perhaps the development of water power in particular, which was bound to take place out in the districts - created an interest for technical subjects. Specialists in this field were highly respected. This has without doubt made a considerable contribution to the progress of the country.

Energy and Society

79. Much attention has been drawn in recent years to the possible limitations in the future global supply of energy. The importance of electricity for the progress of a society has become more evident. The long time it takes to make preparations for an increased supply of energy has meant that the attention to the general development of society has, to a large extent, been connected to the discussion concerning energy resources and energy supplies. Questions relating to social structure and the natural environment are important topics in this respect. Another vital matter is the reliability of the energy supply.

Fourth phase in the electrification, the interaction between electricity and other forms of energy.

80. In Norway, there has been a demand that energy supply and energy consumption should be considered in a wider political relationship. This means that the total-energy aspect has become a central element in the planning of electricity supply and other forms of energy alike, and when providing for a rational use of energy. In addition, in recent years, Norway has found significant fossil energy resources within its territories. All this introduces the fourth phase of the country's electrification: To plan the electricity supply system as part of the country's total energy system, adapted to political requirements concerning social structure and the natural environment.

81. In Norway at the present time, certain institutions are being reorganized, others are being established, to take care of these assignments. The tasks of the electricity supply undertakings will be extended. A Ministry of Environment and a Ministry of Petroleum and Energy have been created. NVE expects to be given more extensive responsibilities and research on energy will be reorganized and consolidated.

Lessons from Norwegian experience

82. What features in the history of electrification of Norway is there reason to emphasize in connection with experiences which may be transferred to countries or areas which are not as yet electrified or fully electrified? At any rate, these areas need not use a whole century for developments - they can build upon all available experience and knowledge. Seen in retrospect certain things should probably have been done otherwise in Norway.

83. I shall list some of the points which, in my opinion, are valuable for developing countries in their struggle to pave the way properly for the development of electricity:

a. All local communities want electricity. When a local community is supplied with electricity, ways of life are altered and the economic life changes in character. It is therefore important to define the aims for the structure of society before shaping a policy for electrification. Electrification of rural districts makes a strong contribution towards preserving the traditional pattern of settlement and will create activities there. If only the centres are electrified, urbanization will increase, and this may lead to problems.

Assuming that it is desirable to preserve the scattered pattern of settlement, one should:

b. Let the local population itself become involved in the plans for electrification and the implementation of these plans. The central authorities must give assistance in various ways - through advice, planning, coordination and financing. The management should be decentralized as much as possible.

c. Ensure that local development take place as part of a nation-wide plan which will provide for a future, interconnected rational system. Instruments to achieve this may be:

- A central coordinating body which takes part in local planning.
- Legislation which ensures the necessary central control.

- Financing arrangements which provide local electricity supply undertakings - with no financial backing- with the possibility to finance the construction of initial systems.

d. Make full use of the recommendations, norms and standards already worked out by international standardization organizations.

e. Require by law that the persons responsible for the daily operation of a supply system are properly qualified. This involve providing facilities for training of personnel in the country in question. A deliberate effort should be made to educate persons from the local communities and encourage them to become interested in the electrification programme.

f. Try to build up domestic industry for the manufacture or preparation of equipment necessary for electrification.

g. Try to build up a technological milieu by establishing an engineers' association, and electrotechnical professional associations in addition to an association of the electricity supply undertakings which are started up.

84. An attempt should be made to base electrification upon domestic resources - where available. Water power sources are of particular interest because they are renewable.

a. Even though one should try to develop the largest sources possible, caution should be shown in starting on large projects which will take a long time to show any profit. The development of small water power sources will probably be the best solution at an early stage of electrification. Developments in Norway, from the many small, through the gradually larger, to the large projects - may be an example of a good arrangement, where suitable resources are available.

b. Diesel power stations are often suitable for the initial electrification of local areas. Diesel stations and water power stations can later supplement each other in the same system. What has been said above about local engagement, operation and training, applies just

as much to systems based on diesel power.

c. Large water power sources can often be developed in stages, but some can only be developed as giant projects, seen in relation to non-industrial consumption. In this case the solution may be the establishment of industry, but the ordinary consumer sector should be supplied first, and here the plans should be very long-term - 30-50 years.

d. Electricity prices should stimulate consumption: that is to say, they should be low in relation to the costs - at least at the start. It is necessary to subsidise the supply undertakings until sales are large enough for them to bear the economic burden alone.

e. It is important to register potential water power. This must be done by competent persons.

f. Hydrological studies should have been performed for many years - before plans are made, and it is decided to build a power station. The authorities must therefore make sure of the necessary competence, and carry out systematic hydrological investigations and registrations in the water courses - even though it does not seem that there will be any development of water power in the immediate future. It can be economically hazardous to develop water power on the basis of meagre hydrological data.

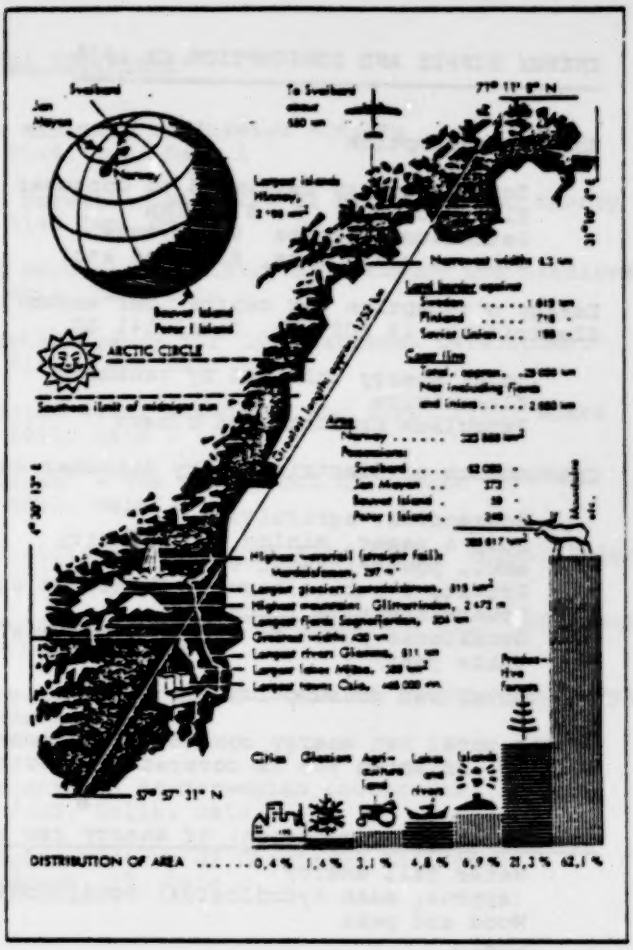
g. Multi-purpose utilization of a water source should be studied before a decision is made to develop its water power.

85. The implementation of a national electrification programme will depend upon the expertise which, at central level, is able to follow up and ensure that it is effected. The best guarantee for the implementation of such a programme is the creation of a limited bureaucracy, with highly competent engineers and economists having a strong desire to help the local population in their struggle to establish, extend and operate their own electricity supply.

86. Central electricity organizations of this type can with advantage seek international collaboration with similar organizations in other countries with which the Government considers it a benefit to be connected.

87. Guidance in the rational and safe use of electricity and the import of, or development of domestic manufacture of electrical consumer equipment should be followed up by the central authorities just as in the case of equipment for the development of the supply systems.

Geographical data about Norway Appendix 1



Location of the Norwegian oil-fields in the North Sea.

Norway and the Norwegian Arctic territory.

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ENERGY SUPPLY AND CONSUMPTION IN 1978

Energy consumption

Total quantity delivered to consumer	563.3 PJ	100%
Electricity 67.1 TWh	241.5 PJ	43%
Petroleum products 6.5 M.tons	276.1 PJ	49%
Others, coal, coke, firewood etc.	45.7 PJ	8%

Energy consumption per capita per annum:
Electricity: 16 800 kWh, Total 141 GJ

Total energy utilized by consumer	444.0 PJ	100%
Electricity	241.4 PJ	58%
Petroleum products and others	202.6 PJ	42%

Consumption of electricity, by consumer category:

Households, agriculture	19.8 TWh	29%
Pulp & paper, mining and industry excl. power-intensive	11.2 "	17%
Private & public serv. & transport etc.	7.3 "	11%
Power-intensive industry	26.5 "	39%
Occasional power to electric boilers (this year)	2.5 "	4%
Total net consumption	67.3 TWh	100%

Of the total net energy consumption, about 22% goes to space heating, of which 60% is covered by electricity.

Total outflow (production) of energy raw materials 1978:

Water fall energy (approx. mean hydrological conditions) [1]	95.3 TWh	343 PJ
Wood and peat	600 cu.m	5 "
Coal	0.47 M.tons	13 "
Crude oil	17.2 "	727 "
Natural gas	13.4 Gm^3	569 "
Sum	approx.	1 700 PJ

Total domestic consumption of energy raw materials for energy purpose was about 670 PJ.

J = joule (international standard unit for energy)
1 kWh equals 3 600 000 joule
Prefix k stands for kilo, i.e. 1 000
" M " " mega, i.e. 1 000 000
" G " " giga, i.e. 1 000 000 000
" T " " tera, i.e. 1 000 000 000 000
" P " " peta, i.e. 1 000 000 000 000 000
1 GJ (gigajoule) = 10^9 joule
1 PJ (petajoule) = 10^{15} joule
1 TWh (terawatthour) = 10^9 kilowatthours (kWh)

1) Status energy of the water, i.e. electric energy delivered from turbo-generator divided by 0.85.

Some useful addresses:

The Royal Ministry of Foreign Affairs
Post Box 8148, Dep. Oslo 1

The Royal Norwegian Ministry of Petroleum and Energy
Post Box 8148 Dep. Oslo 1

The Royal Norwegian Ministry of Industry and Handicrafts
Post Box 8014, Dep. Oslo 1

The Norwegian Agency for International Development
Post Box 8142, Dep. Oslo 1

The Norwegian Water Resources and Electricity Board
Post Box 5091, Oslo 3

"Samkjøringen" - The Power Pool of Norway
Post Box 5093, Oslo 3

The Association of Norwegian Electricity Supply Undertakings
Post Box 277, Oslo 3

The Norwegian Institute of Technology, Univ. of Trondheim
7034 - Trondheim - NTH

The Norwegian Research Institute of Electricity Supply (EFI)
Sem Sælandsvei 11
7034 Trondheim - NTH

The Confederation of Norwegian Industries
Post Box 2435, Solli, Oslo 2

The Norwegian Society of Chartered Engineers
Kronprinsensgt. 17, Oslo 2.

Additional copies of this report may be obtained from the author.

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